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Translational Photoacoustic Imaging for Disease Diagnosis, Monitoring, and Surgical Guidance: introduction to the feature issue

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Abstract: This feature issue of *Biomedical Optics Express* covered all aspects of translational photoacoustic research. Application areas include screening and diagnosis of diseases, imaging of disease progression and therapeutic response, and image-guided treatment, such as surgery, drug delivery, and photothermal/photodynamic therapy. The feature issue also covers relevant developments in photoacoustic instrumentation, contrast agents, image processing and reconstruction algorithms.

1. Introduction

Photoacoustic (PA) imaging is a rapidly growing field in biomedical optics. Applications of photoacoustic imaging cover different areas of biomedical research, ranging from basic biological investigations to translational applications. This feature issue allows for archival publication of the most recent work in translational photoacoustic imaging and provides for broad dissemination in the photoacoustic and optics community.

2. Summary of contributions

After rigorous peer-review, we selected 22 papers to be included in this feature issue. The following summary highlights the scope of excellent work from the authors.

2.1. Invited reviews

This feature issue includes two invited reviews from experts in the field. S. Na and L.V. Wang reviewed the use of photoacoustic computed tomography for functional imaging of human brain. Their article provided in-depth coverage of hardware, reconstruction, and in vivo experimental details of the functional brain imaging systems [1]. A. Wiacek and M.A.L. Bell reviewed photoacoustic-guided surgery [2]. Their article covers multiple aspects of the use of photoacoustic imaging to guide both surgical and related non-surgical interventions, spanning from structures within the head to contents of the toes. Outlooks for future technological developments and new research directions are discussed in both reviews.

2.2. PA imaging of human subjects or human tissue samples

Five articles reported photoacoustic imaging of human subjects or human tissue samples. Nyayapathi et al. presented the results of PA dual-scan mammoscope from 38 patients [3]. Their

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study found that compared to contralateral healthy breasts, tumor-bearing breasts contained vessels of larger diameter and exhibited stronger variations in the background signals. In another breast imaging study, Wang et al. imaged nine patients with intraductal lesions and eight patients with benign lesions. They found that PA combined with B-mode and color doppler ultrasound can achieve higher sensitivity and specificity than ultrasound alone [4]. For skin cancer imaging, Hult et al. compared photoacoustic imaging with histopathological examination in determining the dimensions of 52 ex vivo human melanomas and nevi [5]. Using multi-wavelength (59 wavelengths) spectroscopic photoacoustic imaging, the authors found that the tumor dimension determined by PA strongly correlated with those determined by histopathological examination.

Two studies reported the use of PA for imaging of blood oxygenation in human subjects. The article from Bunke monitored the local changes in oxygen saturation after adrenaline injection in human forearm skin [6]. Their study found that PA can spatially resolve oxygen saturation changes in different layers of tissue. In a related study, Merdasa reported the PA-based monitoring of sO2 in a human ischemia-reperfusion model [7]. The article indicates that PA can be used as a non-invasive diagnostic tool for micro-vascularization in related disorders.

2.3. Preclinical imaging in animal models or tissue phantoms

Preclinical research in animal models represents an essential step in translational imaging. Two articles in this feature issue reported studies conducted in animal models or tissues. Liu et al. introduced a new contrast agent, chlorophosphonazo III (CPZ III), for PA imaging of intracellular calcium [8]. Their results demonstrated that CPZ III could serve as a robust contrast agent for microscopic PA imaging of calcium concentrations. Huang et al. reported an empirical assessment of laser safety for photoacoustic-guided liver surgeries [9]. By investigating swine liver models, the authors found that the laser safety limit for PA liver imaging could potentially be increased without causing any cell damage.

2.4. Image reconstruction and data processing

Image reconstruction, data processing, and numerical simulations will facilitate the development of translation photoacoustic imaging systems. This feature issue contains ten articles in these areas.

In particular, machine learning technologies have been widely used in PA research. Park et al. compared different machine-learning models for classifying healthy versus atopic dermatitis conditions from images acquired by raster-scanning optoacoustic mesoscopic [10]; Yuan et al. reported a hybrid deep learning network for segmentation of vascular structures in PA images [11]; Sharma reported a conventional neural network for improving the spatial resolution and reducing the noise in acoustic-resolution photoacoustic microscopy [12]; and Rajendran et al. introduced a deep-learning approach to improve the tangential resolution in circular-scan PA tomography [13].

Two articles reported the development of new PA image reconstruction algorithms. Awasthi et al. reported a singular value-based plug-and-play priors method to improve the signal-to-noise ratio in PA imaging [14]. Yang et al. introduced a lag-based delay multiply and sum method with coherence factor to improve the spatial resolution and contrast of PA imaging [15]. The algorithm was also applied in patients with ovarian cancer and found that the new algorithm can improve cancer diagnosis.

In terms of data processing, Khodaverdi et al. reported an automatic threshold selection algorithm to distinguish a tissue chromophore from the background based on an adaptive matched filter [16]. Through imaging of tumor models, their method demonstrated accurate estimation of phantom inclusions and tumors. Erlov et al. introduced a regional motion correction method of PA imaging using interleaved ultrasound images [17]. Their method provided significant reduction in mean square error between PA images with human motions.

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In terms of numerical simulation, Bao et al. introduced a digital breast phantom for PA tomography [18]. Their phantom contained realistic acoustic and optical properties and could facilitate the development of PA breast imaging technologies. Liang et al. investigated the acoustic impact of human skull on transcranial PA imaging [19]. Their study found that the ring-array-based PA imaging system had more tolerance to the skull-induced acoustic distortion. Finally, Hill et al. introduced a framework to characterize and describe acousto-optic interaction in optically scattering media [20]. While the framework was developed for a related technique, ultrasound optical tomography, it also has potential to be used in PA imaging.

2.5. Imaging hardware

Two articles are related to the development of PA systems. Kratkiewicz et al. discussed technical considerations when developing a PA system based on the Verasonics research ultrasound platform [21]. The article covered a comprehensive review of experimental considerations, system settings, image reconstruction, and data processing methods. Metwally et al. described the development of a multi-functional preclinical device for the treatment of glioblastoma [22]. The device combined focused ultrasound sonication for blood-brain barrier permeabilization, photothermal therapy, and PA-based temperature monitoring. The preliminary results indicate that the device has great potential for the treatment of glioblastoma.

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